

Cryogenic Summary - Testing D2L105 in MAGCOOL

K. C. Wu

5/20/03

- Description
- Operating Summary
- Tests Performed
- Detail Operation
- Test Conditions
- Summary

Specific of D2L105 Test

- In Nov. 2002, ~ 100 cc of compressor oil was introduced into the system from operating error.
- Through 8 days of helium circulation, we found essentially no oil left in the piping. Majority of oil appears to have deposited in D2L104 during its 3 months test.
- To prevent any minute chance of oil from entering D2L105, filters are installed downstream of the cooldown and JT supply lines. These filters, made by SOFRANCE, have been used for years in preventing particulates from entering circulating compressor, ejector and turbine. The filter should be able to collect solid oil, and possibly to retain oil after warmup.

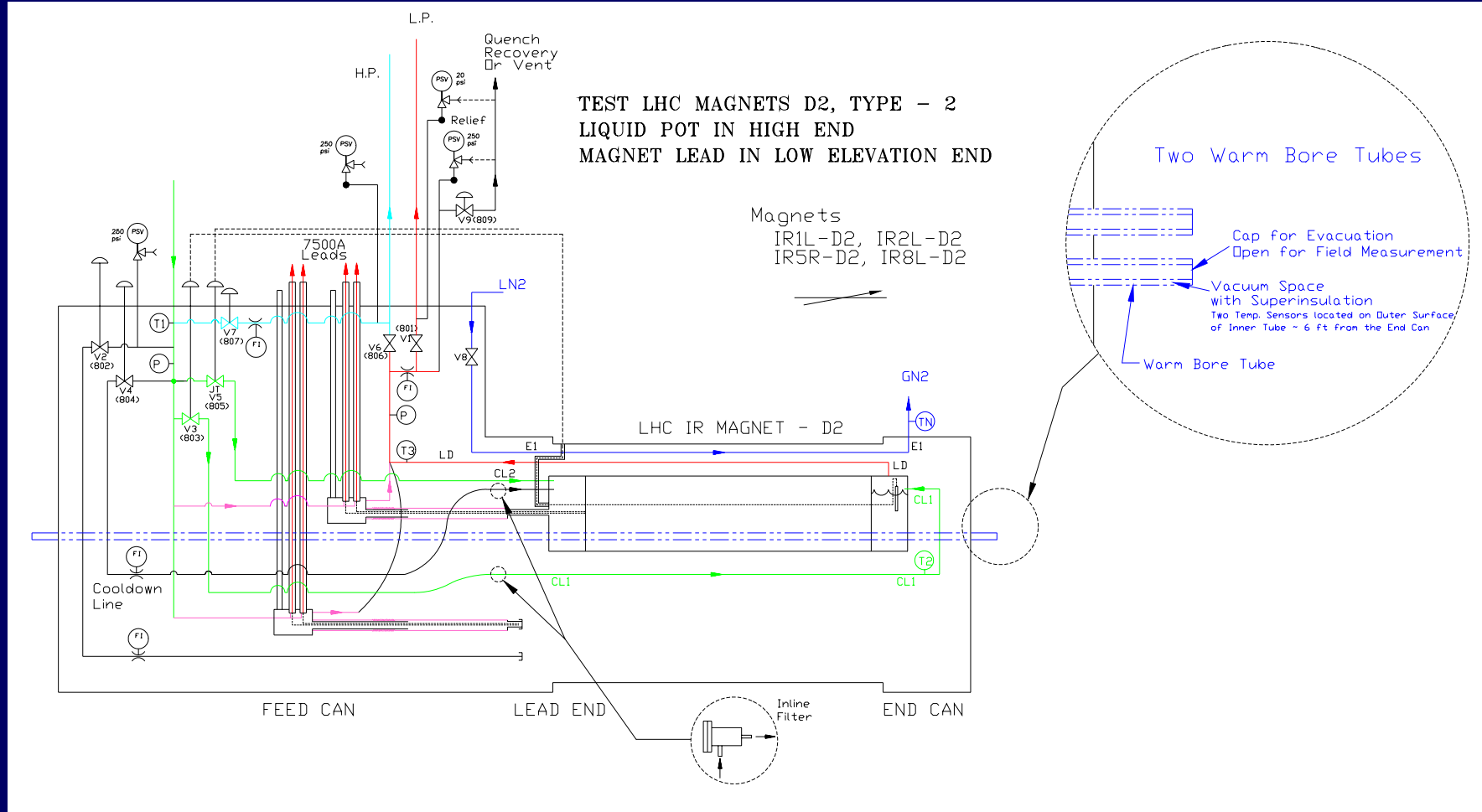
Specific of D2L105 Test

- After D2L105 was warmed up at the end of the test,
 - Small quantity of oil is found at the inlet of the filter installed in the Cooldown-Warmup line.
 - ~ 1 cc of oil is found inside the filter housing, but no oil in the outlet nozzle of the filter.
 - Lines for the JT feed are very clean and has no sign of oil.
 - The outlet nozzle of D2L105 shows trace of oil film.
 - No oil is found in the Lead-End End Volume.
 - Very small amount of oil is found in the End Volume of the Non-Lead End.
 - Oil is wiped out from the End Volume of D2L105.

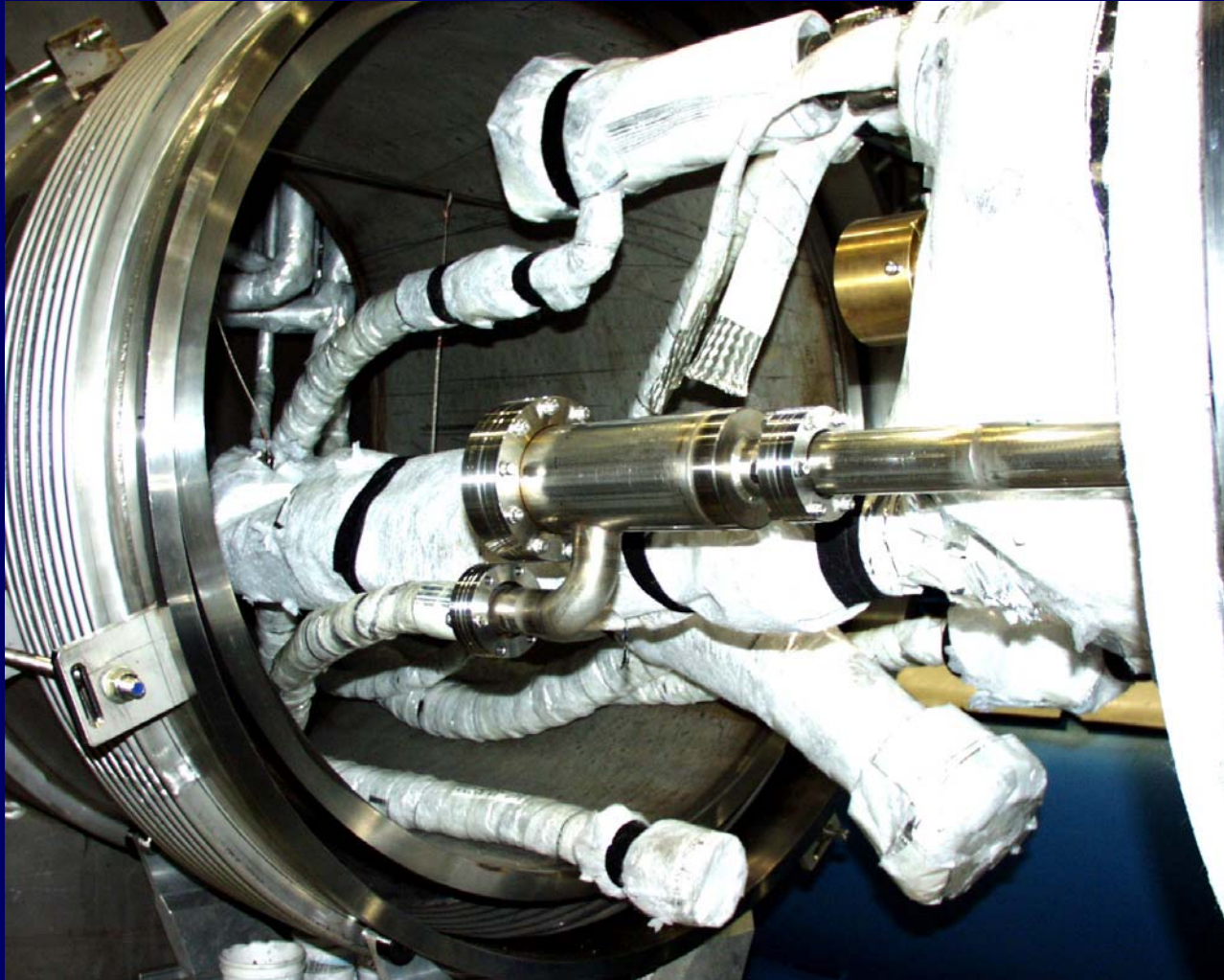
General Description - D2L105

- Non-lead end is higher than the lead end by ~ 3 cm.
- 0.28 % slope (slightly less than 0.36 % in LHC IR8) corresponding to ~ 5.5 % difference in liquid level between the lead end and non-lead end.
- Warm bore tubes inserted. Tests have been performed with warm bore tubes evacuated and opened for field measurements.
- Information on the Warm Bore Tube and measuring device can be obtained from
 - A. Marone - andym@bnl.gov
 - G. Ganetis - ganetis1@bnl.gov
 - D. Sullivan - dans@bnl.gov

Flow diagram of D2L105 with Warm Bore Tubes and Two Filters – Non-lead end is higher.



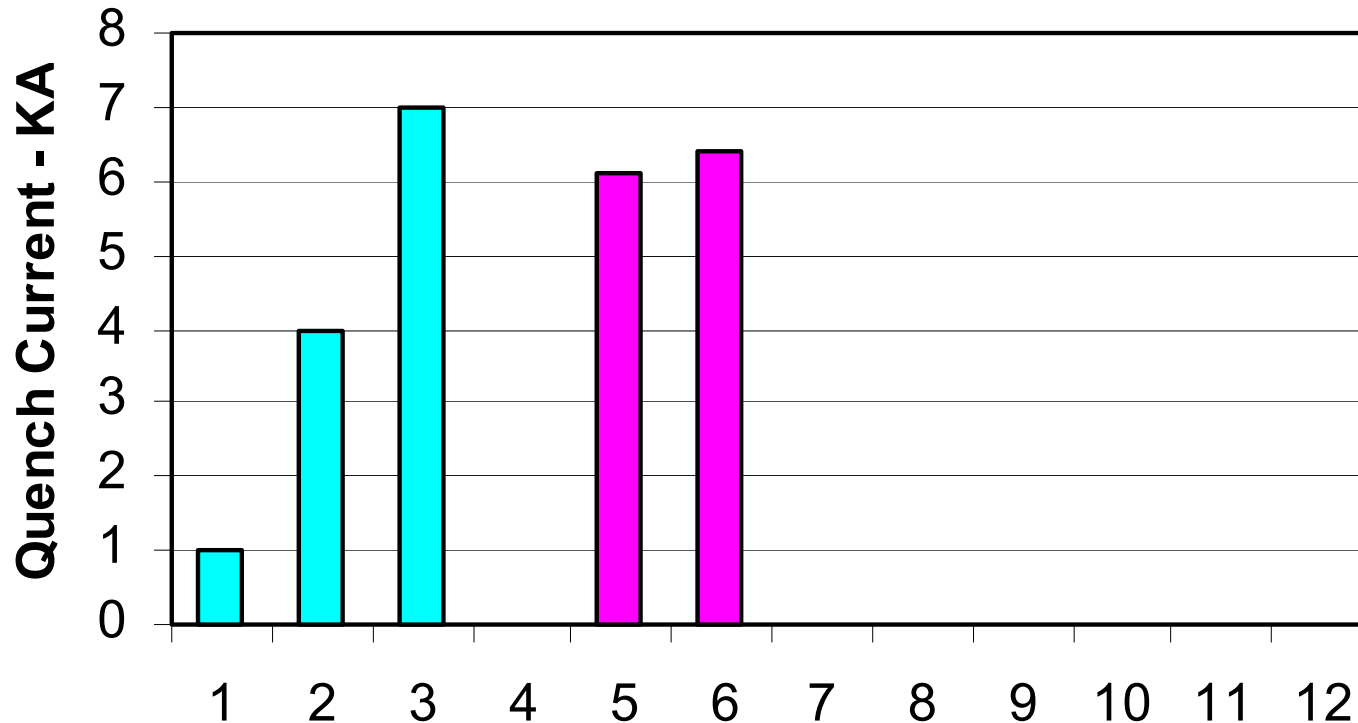
Filters are installed in front of supply nozzles on D2L105, Upper filter – cooldown supply in lead end, Lower filter – JT supply to non-lead end



Tests Performed for D2L105

- 1st test group (forced flow cooling ~ 4.6 K),
 - Shut off - 1000 A (4/22)
 - Strip heater - 4000 A (4/22)
 - 1st quench - 7009 A (4/22)
- 2nd test group (liquid helium ~ 4.6 K),
 - 1st quench - 6082 A (4/23)
 - 2nd quench - 6414 A (4/23)

Quench Performance of D2L105 with Warm Bore Tubes Evacuated (1000 A is shut off, 4000 A is strip heater)



Quench - No. 1 Shut off

No. 2 Strip Heater

No. 3 Forced Flow,

No. 5-6 Liquid Cool

Operation (3/27 – 4/13)

- 3/27 Close vacuum enclosure. Pump on insulating vacuum.
- 3/28 Weld the feed through connector.
- 3/31 Initial pump down, pressure test, electrical and electronic connections
- 4/1 Pump & purge, electrical connection, set up for warm measurement
- 4/2 - 4 Warm measurement
- 4/5 – 6 No work in weekend
- 4/7 – 11 Work on transporter and mole
- 4/12 – 13 No work in weekend

Operation (4/14 – 22)

- 4/14 - 15 Evaluate condition of transporter and mole
- 4/16 - 19 Cooldown I
Takes 3 days (~ 64 hours) to complete
(probably due to oscillation in process control,
don't know exact cause)
- 4/19 - 20 Wait at 100 K (Easter weekend)
- 4/21 100 – 5 K Cooldown ~ 20 hours using two
expanders, E19 & E20.
- 4/22 Reach test condition for forced flow,
Cold check, 1000A shut off,
4000A strip heater quench,
1st quench 7009A with stops at 5000 & 6800A

Operation (4/23 – 27)

- 4/23 Switch to liquid cool.
- 4/23 1st quench 6082A – approximately two hours into liquid cool. Temperature and liquid are stable. Liquid level 87% in the lead end and 82% in the non-lead end. JT in lead end crack opened at $\sim 5\%$.
- 4/23 2nd quench 6414A – Liquid levels are 86% & 81%. JT in lead end small open at $\sim 15\%$.
- 4/23 Switch to forced flow for field measurement.
- 4/24 Perform field measurement – 1 AC cycle and 5 DC loops.
- 4/25 Perform field measurement – 2 AC cycle and 3 DC loops.
- 4/26 – 27 Wait at test condition through weekend

Operation (4/28 – 30)

- 4/28 Perform 1 AC cycle,
 Encounter power supply and communication
 problem during the DC loop,
 Push Crash button causing strip heater to
 quench at 4500A,
 Perform diagnosis run to 3000A
- 4/29 Perform field measurement – 1 AC cycle and
 3 DC loops.
 Finish field measurement for left aperture.
 Move measuring device to the right aperture.
- 4/30 Perform 1 AC cycle and 6 DC loops.

Operation (5/1 – 7)

- 5/1 Perform 2 AC* cycle and 5 DC** loops.
*During the 1 AC cycle, lead flow control for DC loop type was used by mistake causing the leads to quench at 2767A.
**Data for 1 DC loop is not good.
Complete field measurement for right aperture
- 5/2 - 4 Start Warmup at 9:30 on 5/2,
Warmup completed at ~ 24:00 on 5/4,
Total warmup time ~ 39 hours
- 5/5 Verify vacuum integrity after warmup.
- 5/6 - 7 Disconnect pipe to D2L105,
inspect line and filter for oil,
~ 1 cc of oil is collected from the filter housing
in the Cooldown-Warmup supply line.

Operation (5/8 – 19)

- 5/8 - 19 Inspect oil in D2L105.
No oil in the End Volume in the Lead End,
The two cold pipes, attached on D2 for use
as the supply and the return line in the test,
are clean.
Tiny amount of oil is found in the End
Volume in the Non-Lead End.
Wipe out trace of oil in the non-lead-end end
volume.

Test Conditions

- Forced flow cooling - 12 atm, 4.6 K & 55 - 60 g/s
- Warm bore tube evacuated

Pressure is 0.120 Torr inside warm bore tube

Temperatures are

-90 / -110 F in left aperture

-57 / -77 F in right aperture

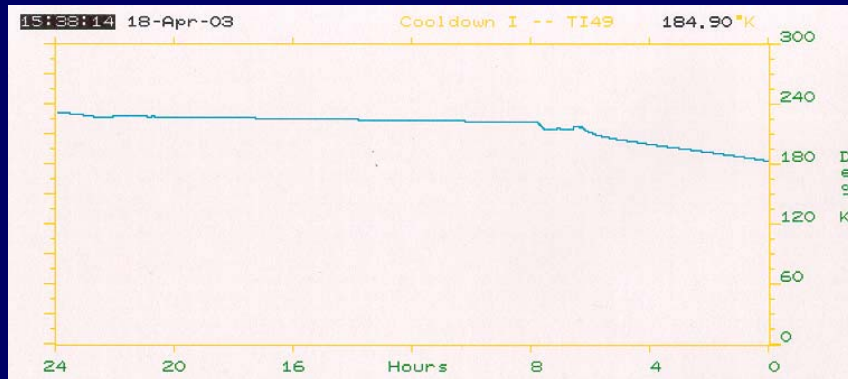
- Liquid helium cooling – 1.36 atm, ~ 4.6 K

Liquid level in non-lead end ~ 82% (~10 cm above coil,
~ 5 cm below vent)

in lead end ~ 86% (~12 cm above coil,
(~ 3 cm below vent)

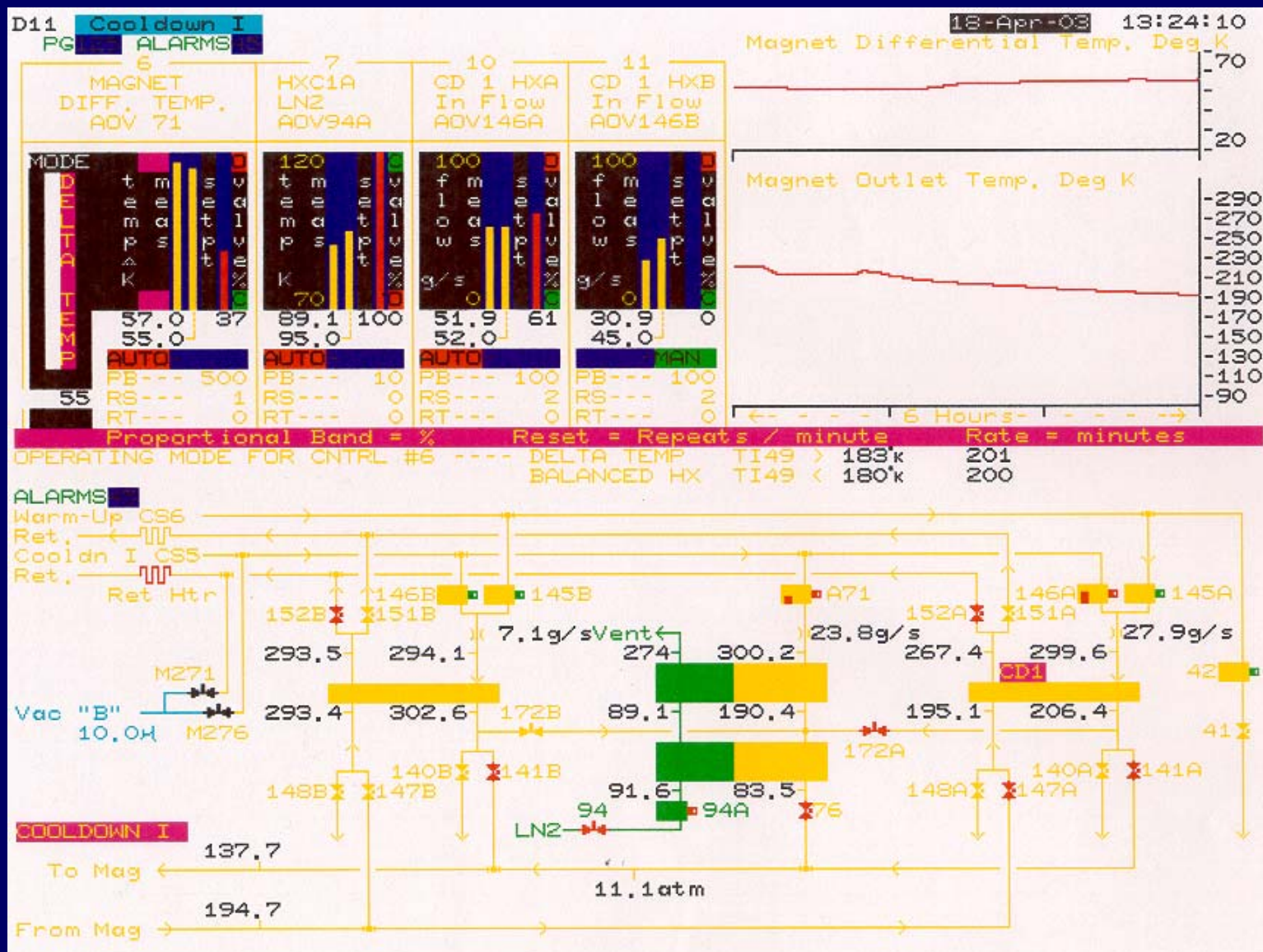
Cooldown from 300 – 100 K for D2L105

(4/16 - 4/19/03)



- 100 K Cooldown time ~ 64 hours
- Use between 40 to 57 g/s of helium flow. Flow oscillates probably due to controller.
- Cooldown rate:
 - ~ 2.5 K/hour 300 – 240 K
 - ~ 2 K/hour 240 – 210 K
 - ~ 3 K/hour 210 – 180 K
 - ~ 5 K/hr 180 – 100 K

Operating Condition for 100 K Cooldown of D2L105



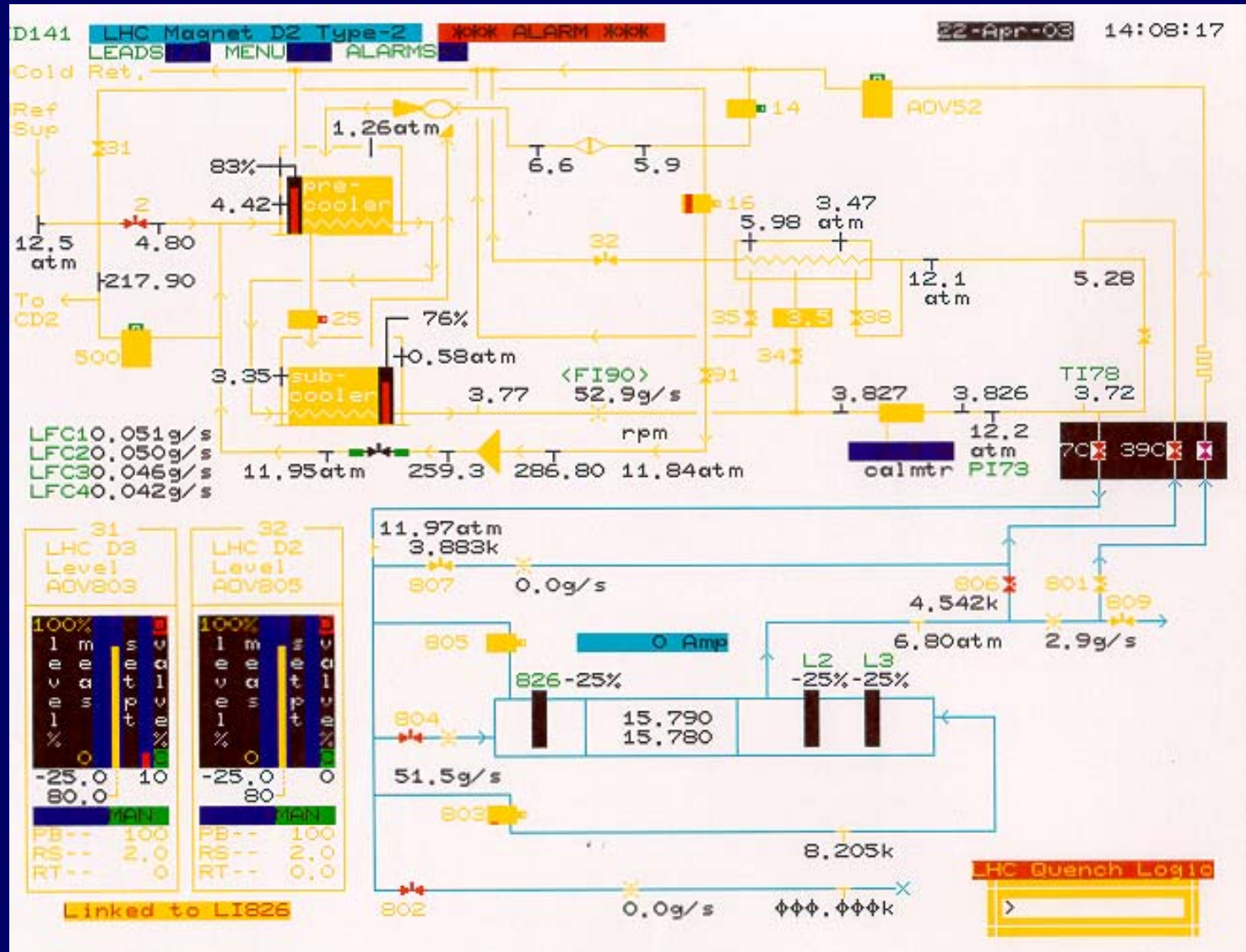
Cooldown from 100 – 5 K for D2L105

(4/21 – 4/22/03)

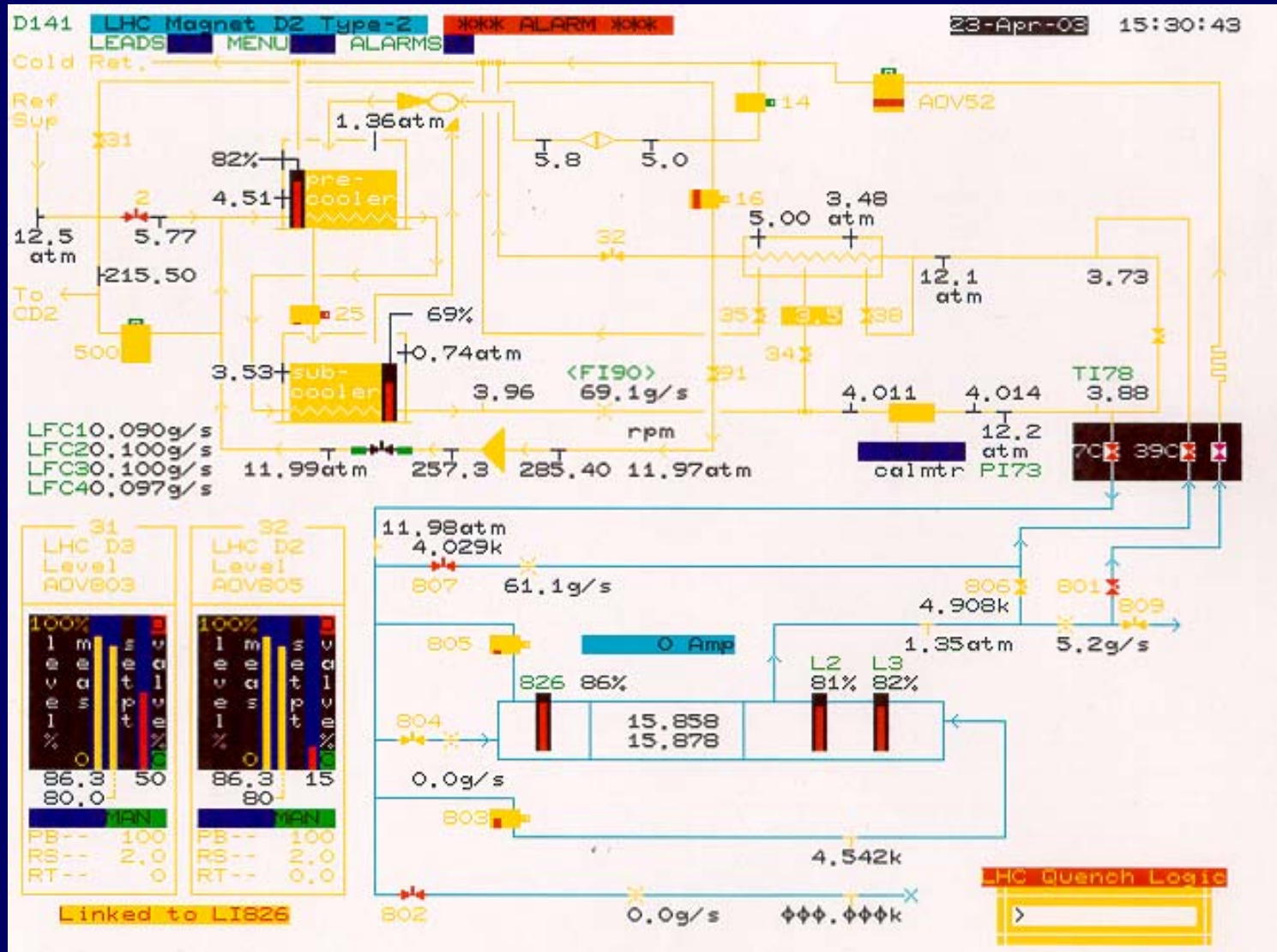


- Cooldown time (90 to 20 K) is 8 hours, ~ 9 K/hr using E19 & E20 (at ~ 190 rpm).
- Cooldown time (20 to 5 K) is ~ 14 hours, using E19 & E20 (at ~ 150 rpm).
- Total cooldown time from 90 K to test condition is ~ 24 Hours

Forced Flow Cooling of D2L105 Prior to 7009 A Ramping (Warm Bore Tube Evacuated with 0.120 Torr Pressure)



Liquid Cooling of D2L105 Prior to 6414 A Ramping (Warm Bore Tube Evacuated with 0.120 Torr Pressure – 4/23/03)

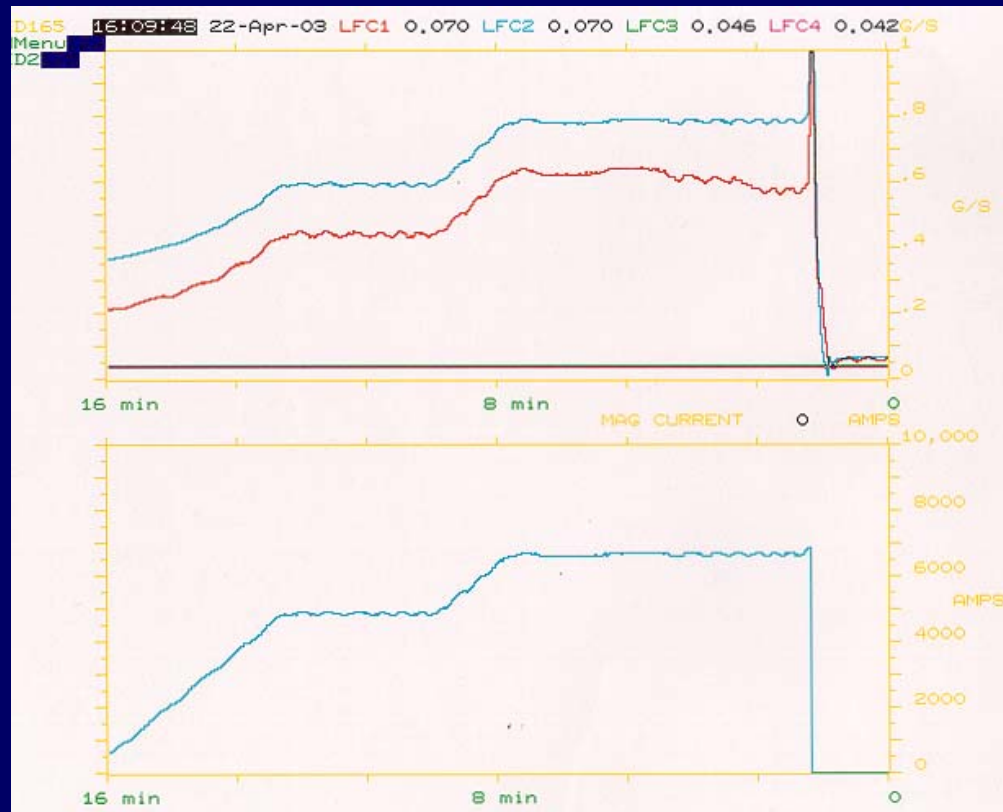


Lead Flow and Current During Ramping of D2L105

Ramp rate is 20 A/s. Below 10 A, Tare flow is 0.07 g/s. Above 10 A, Tare flow is 0.20 g/s for (+) lead & 0.35 g/s for (-) lead. Need to wait for voltage recovery of the (-) lead at 5000 A for about 3 min.

Upper Figure: Lead Flow – **Blue** for (-) Lead and **Red** for (+) Lead.

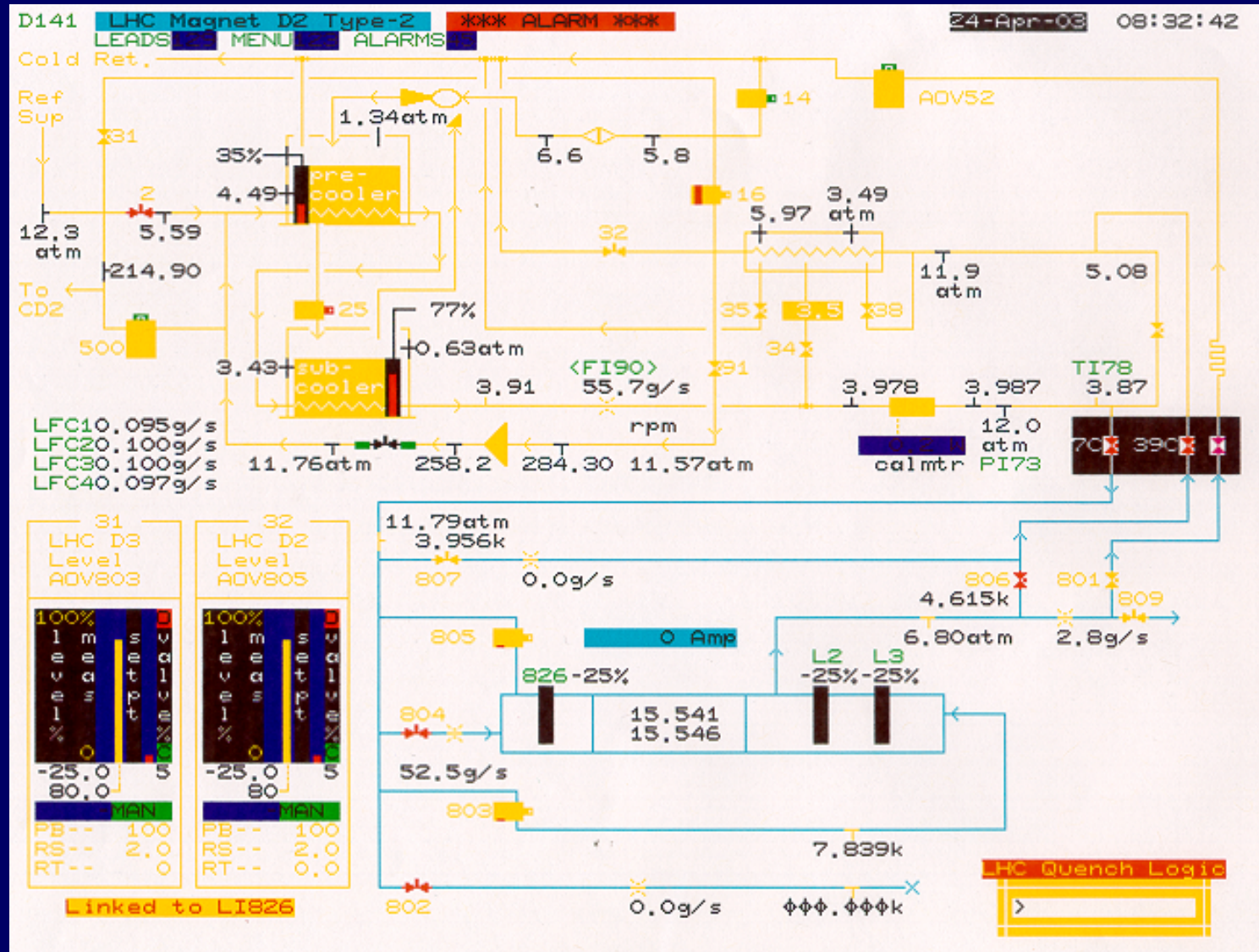
Lower Figure: Current as a Function of Time



Current Leads

- Operate same way as previous D2 magnets.
- Separate flow controllers for the 7500 A leads
- Flow control similar to previous D2s.
- The (-) lead demands more flow than the (+) lead
 - For quench test at 20 A/s ramp rate,
 - The tare flow are 0.20 g/s for (+) lead and 0.35 g/s for (-) lead
 - Wait ~ 2 minutes at 5000 A for the (-) lead to recover the voltage developed before ramping current above 5000 A.
 - Warm end of the (+) lead becomes cold and needs to reduce Tare flow to 0.18 g/s.
- Unused leads are set at 0.070 g/s and 0.100 g/s.

Forced Flow Cooling of D2L105 - Warm Bore Tube Open with 75 F Nitrogen Flow for AC/DC Cycling

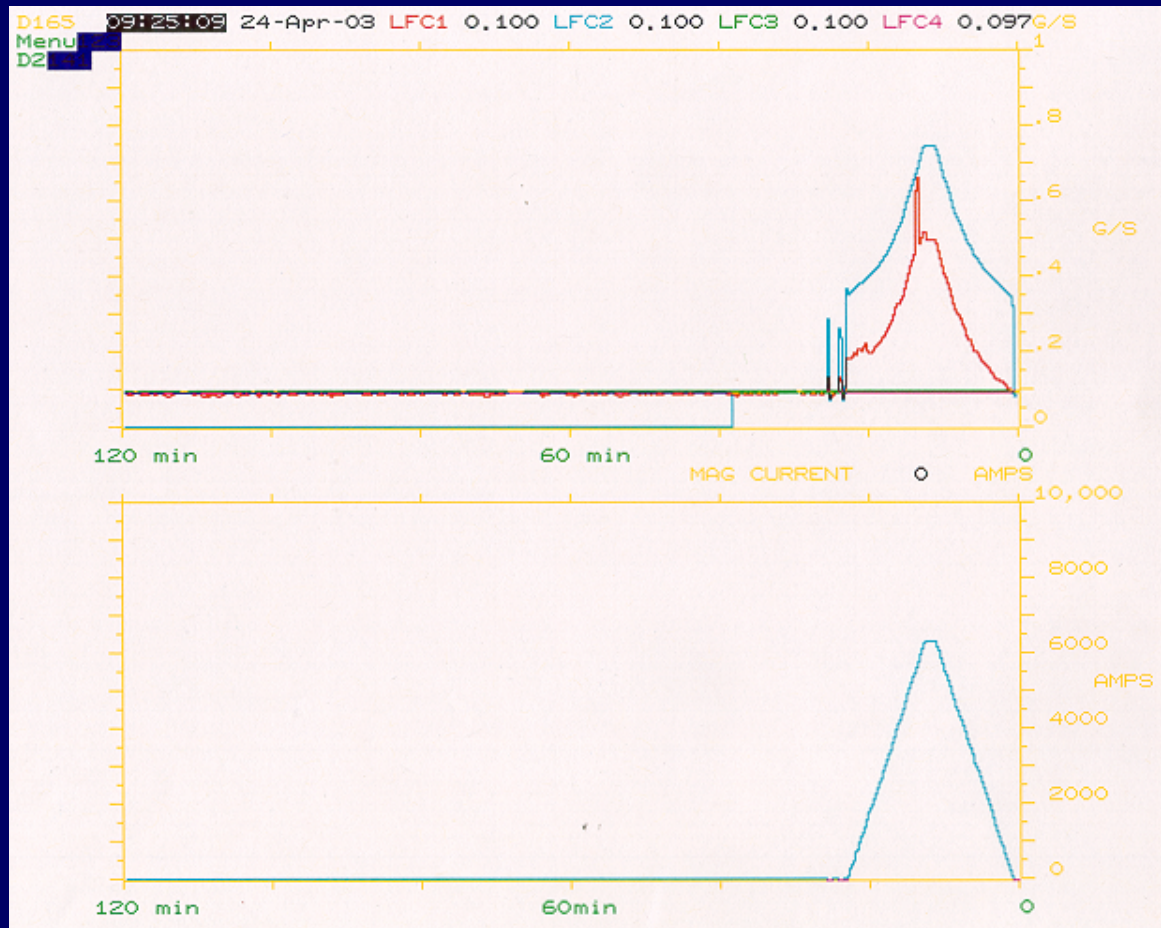


Lead Flow and Current During AC Cycle.

Upper Figure: Lead Flow – Blue for (-) Lead and Red for (+) Lead.

Lower Figure: Current as a Function of Time

Ramp rate is 10 A/s and is ramped to 6400 A according to test plan.



Lead Flow and Current During DC Loop of D2L105

Upper Figure: Lead Flow – Blue for (-) Lead and Red for (+) Lead.

Lower Figure: Current as a Function of Time

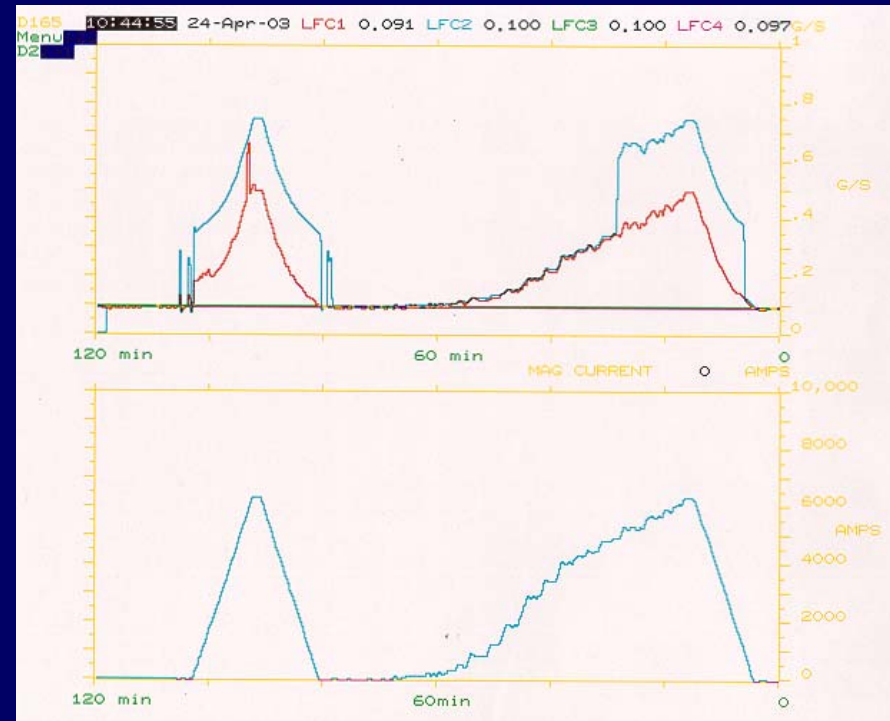
Note: DC loop is the set of curve on the right. The curve on the left is AC cycle.

Ramp rate is 10 A/s. 70 seconds stop at several currents during ramp up. Ramp down at 10 A/s without stop.

It takes about 40 min to reach 6400 A, there are time for the leads to be cooled. The lead flow should approach design value as shown in the (+) lead. As we know, there is a defect in the (-) lead and requires more lead flow even through it takes 40 min to reach 6400 A.

Tare flow is set at 0.10 g/s for the (+) leads for all currents to 6400 A.

Tare flow for the (-) lead is set at 0.10 g/s below 2000 A and 0.35 g/s afterwards.



Current Leads

- Flow control for AC cycle and DC loop are similar to that for D2L104
 - For AC cycle at 10 A/s ramp up directly to 6400 A,
 - Tare flow is ~ 0.15 g/s for (+) lead, (warm end becomes too cold, reduce to 0.12 and finally 0.10 g/s)
 - Tare flow is ~ 0.38 g/s for (-) lead
 - For DC loop at 10 A/s with 70 seconds stop at various pre-selected currents,
 - The tare flow is 0.10 g/s for (+) lead for all currents
 - The tare flow is 0.10 g/s below 2000 A and 0.35 g/s afterward, (or reduced back to 0.10 g/s below 2000 A with stop during ramp down)
- Unused leads are set at 0.100 g/s.

Problems

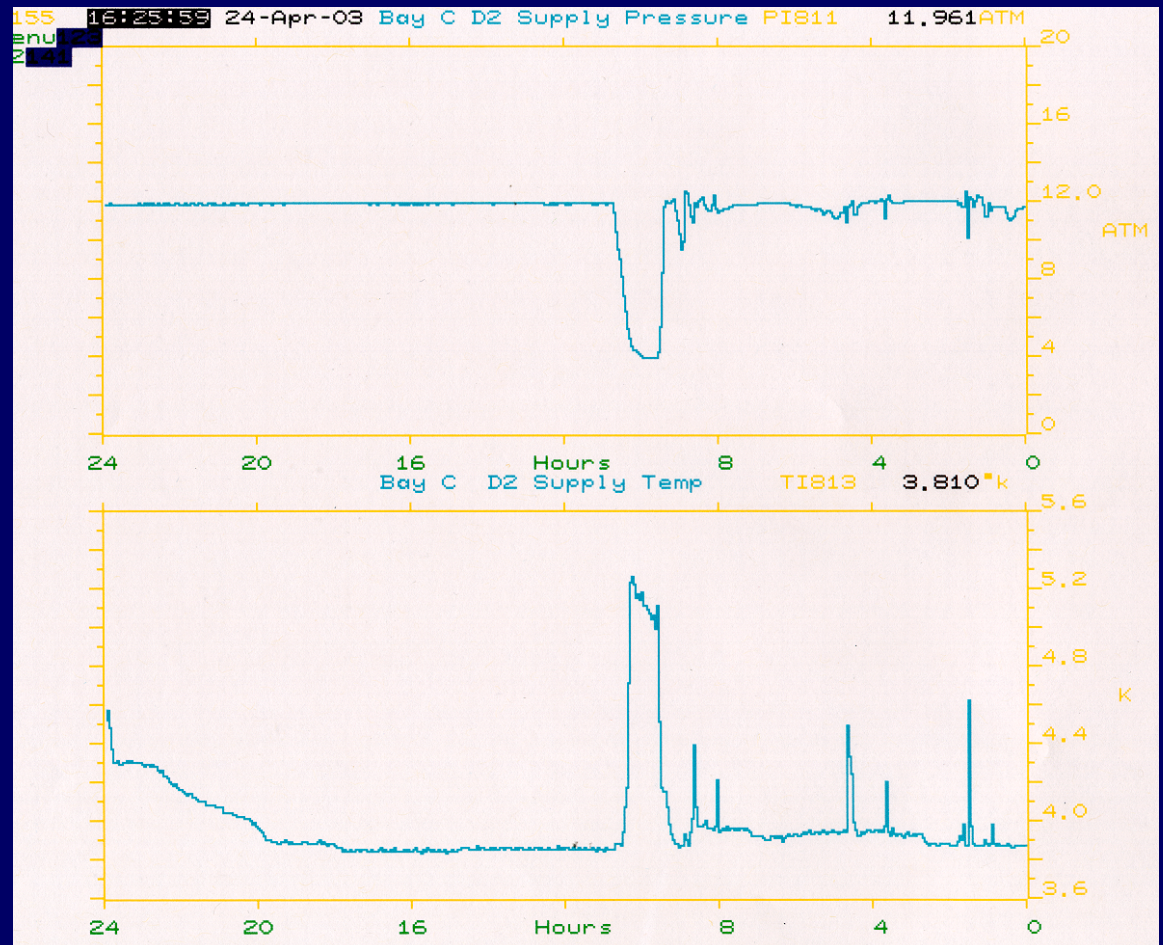
- During switching over to liquid cool on 4/23, there are leakages through DOV806 & 804. We need to apply air to the top of the actuators so that these two valves can be shut tight. We'll readjust the valve for next D2.
- On 4/23, a pressure controller in the HEUB helium refrigerator mal-function. Minor perturbation in pressure and temperature supply to D2L105 was observed for tests performed on 4/24 (one day only). Temperature variation of 0.5 K at inlet to D2L105 for 4/24 are given. However, there is no change to the CERNOX sensor installed in the middle of D2 because the time duration is very short.
- In all other tests, the temperatures are very stable.

Fluctuation of Pressure and Temperature due to Malfunction of Pressure Controller in HEUB.

Upper Figure: Fluctuation of Pressure

Lower Figure: Fluctuation in Temperature

In these figures, field measurements are performed between 0 and 7 hours. The maximum temperature recorded is ~ 0.5 K. Duration of the fluctuation is very short. Temperature reading based on the CRNOX installed in the middle of D2 is stable.



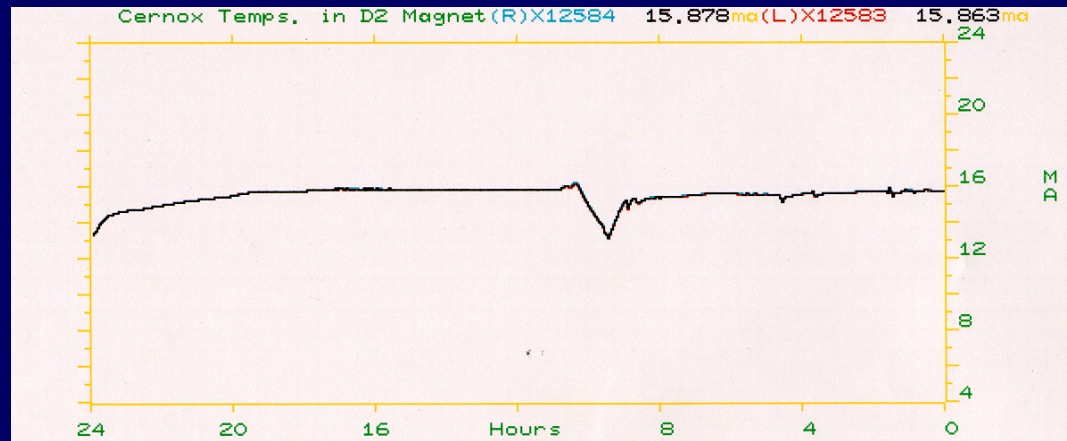
Temperature and Lead Flow During Field Measurement.

Upper Figure: Electric Current of CERNOX temperature Sensor

Lower Figure: Lead Flow in the AC Cycle and 5 DC Loop

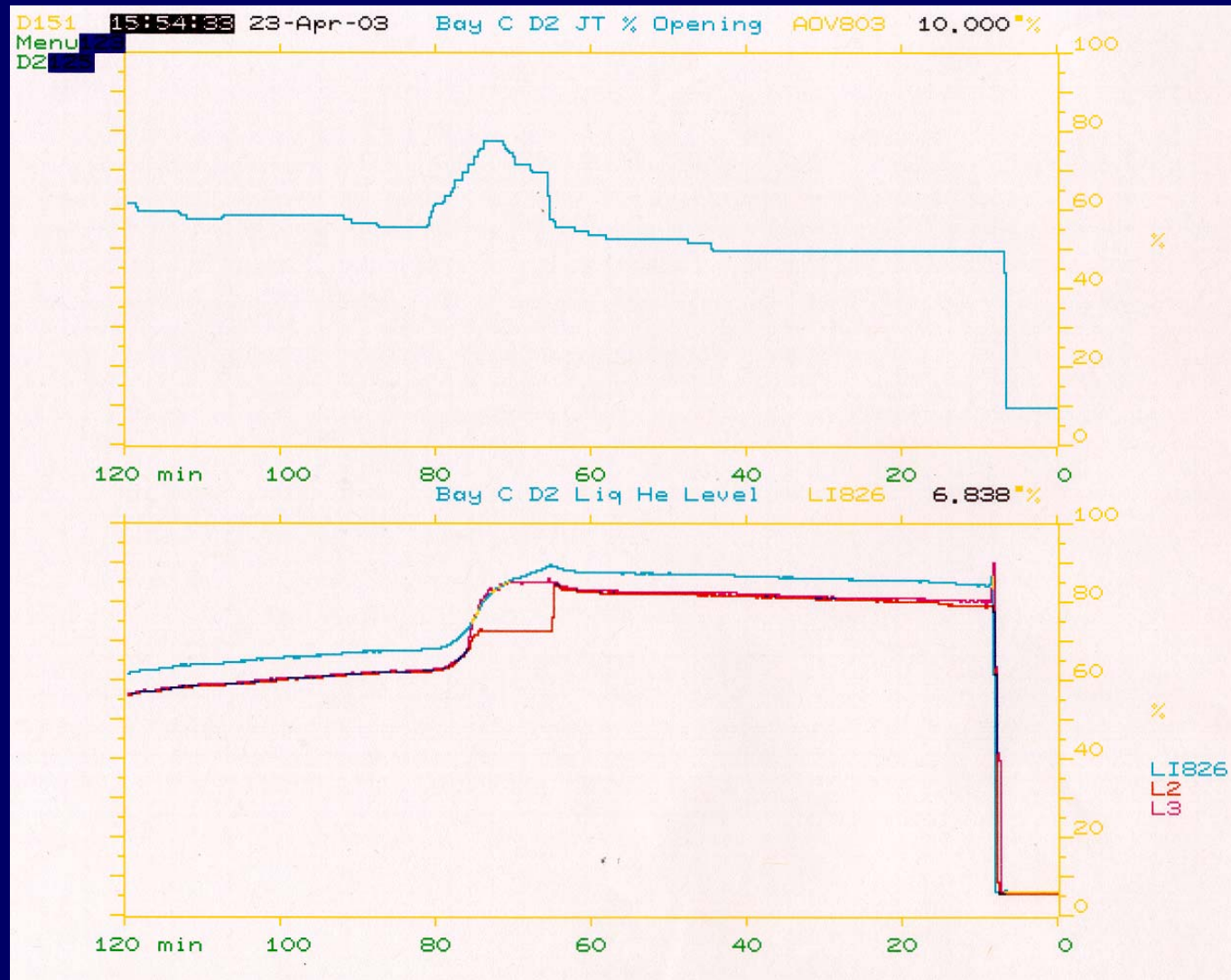
In these figures, field measurements are performed between 0 and 7 hours as shown in lower figure.

Temperature reading based on the CRNOX installed in the middle of D2 is stable.

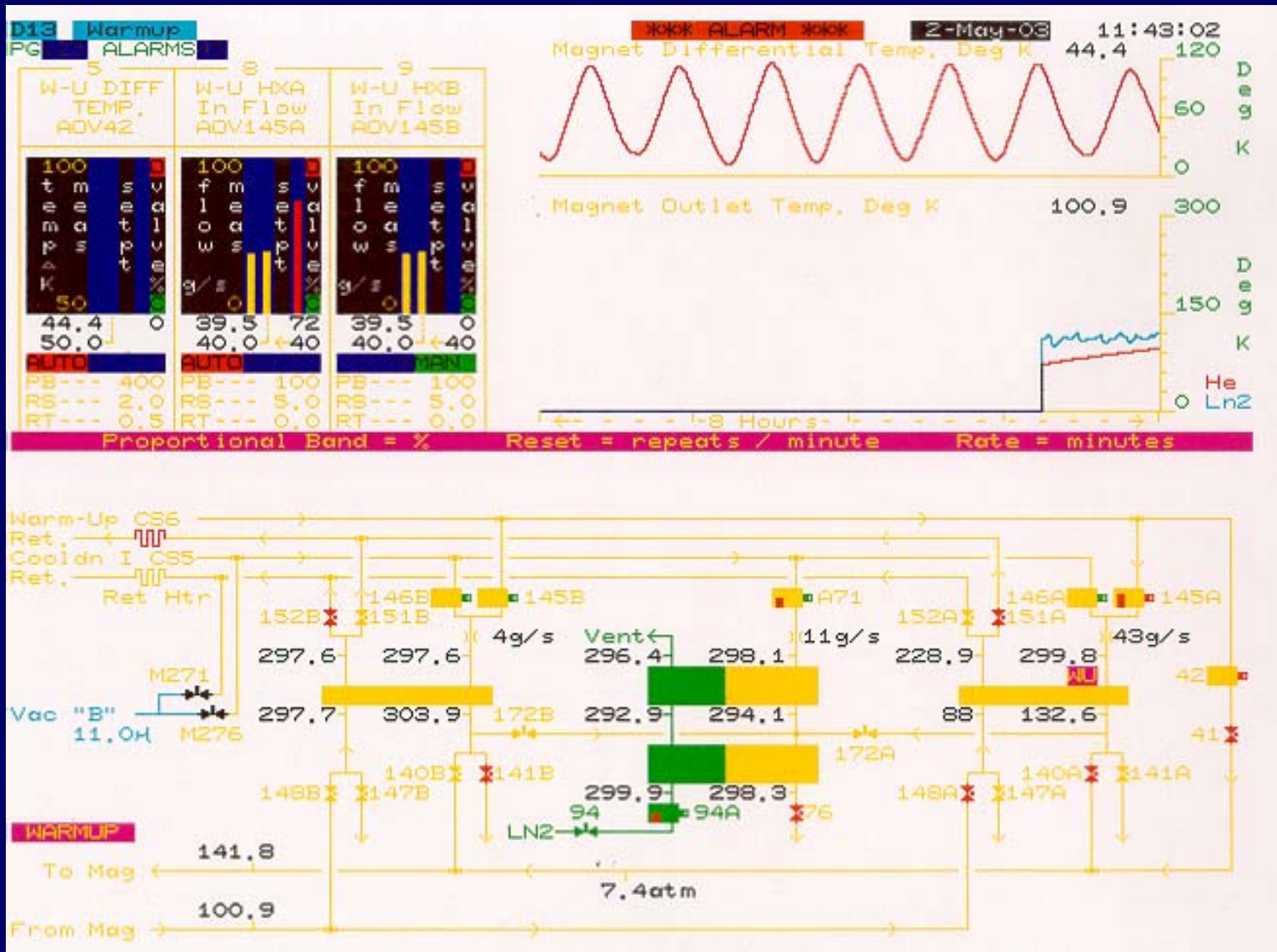


Level Control for Liquid Cooling of D2L105 – 4/23/03

(JT manually set at ~50%, Lead End 86%, Non-Lead End 82%)

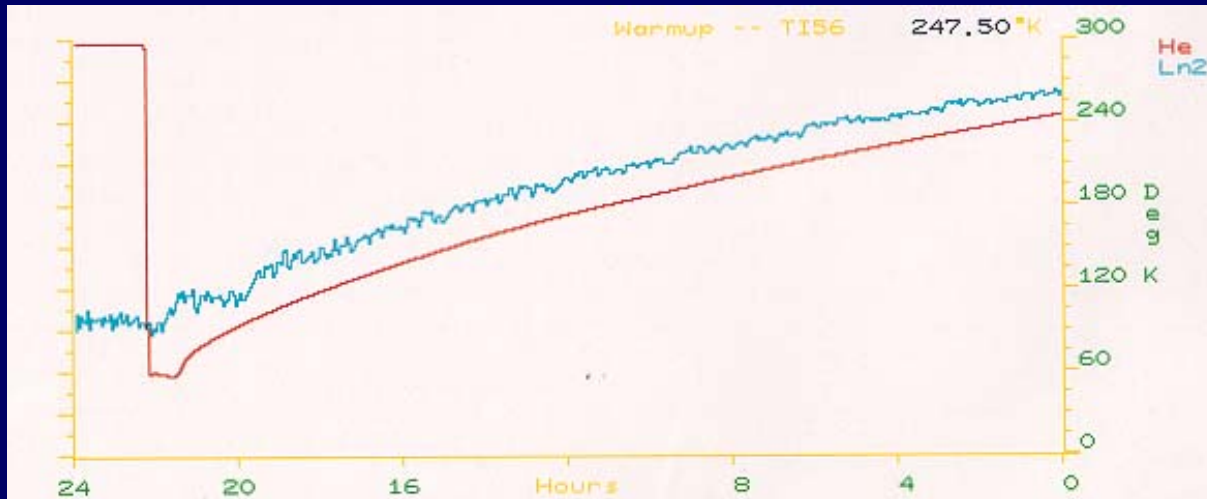


Process Control for Warmup D2L105 – 5/2/03

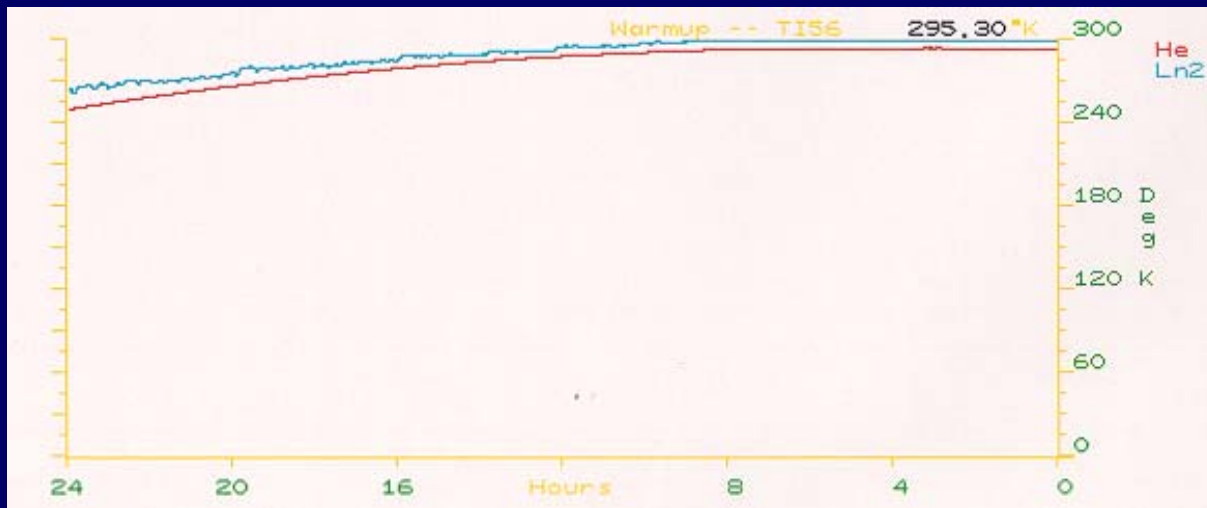


Warmup of D2L105 – from 35 to 300 K

Total time equals ~ 39 hours.



60 – 247 K
in 22 hours



247 – ~ 300 K
in 17 hours
Warmup
completed at
 ~ 8 hours on
the horizontal
axis.

Inline Filter in the Supply Line for Cooldown-Warmup



After D2L105 is warm, the filter is opened for inspection.

There are small quantity of oil at the inlet to the filter in the cooldown-warmup line. Essentially no oil at the outlet of the filter. The filter housing collects ~ 1 cc of oil.

Inline Filter in the Cooldown-Warmup Supply Line (2)



There are some oil on the end flange and the copper seal. The amount of oil on the filter element is minimum.

Summary

- Complete field measurement for D2L105 with two warm bore tubes. Warm bore tubes are evacuated for quench tests. In field measurement, warm bore tubes are open with 75 F nitrogen flow. Temperature increase due to opening of warm bore tube is insignificant.
- After the magnet is warmed up at the end of the test, ~ 1 cc of oil is found in the housing of the filter installed in the cooldown-warmup supply line. Essentially no oil at the outlet of the filter, although it is not 100% dry. Trace of oil film has been observed in a few locations in the return line, especially on the Conflate copper gasket. No oil is found in the JT line. Tiny amount of oil was found in the End Volume in the non-lead end. The oil was wiped out and D2L105 appears clean.